IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

PATENT APPLICATION

REQUEST FOR FILING APPLICATION
Under Rule 53(a), (b) & (f)
(No Filing Fee or Oath/Declaration)
(Do NOT use for Provisional or PCT Applications)
Use for Design or Utility Applications

00909

RULE 53(f) NO DECLARATION

Hon. Commissioner of Patents
Washington, DC 20231

Atty. Dkt. P 284123 | P-0218.010-US
M# | **Client Ref**

Date: November 21, 2001

J1040 U.S. PTO 09/989700 11/21/01

Sir:

1. This is a Request for filing a new Patent Application(☐ Design ☒ Utility) entitled:

2. (Complete) Title: LITHOGRAPHIC APPARATUS, DEVICE MANUFACTURING METHOD, AND DEVICE MANUFACTURED THEREBY

without a filing fee or Oath/Declaration but for which is enclosed the following:

3. ☒ Abstract 1 page(s).

4. 25 Pages of Specification (only spec. and claims); 5. ☐ Specification in non-English language

6. 11 Numbered claim(s); and

7. ☒ Drawings: 15 sheet(s) ☐ 1 set informal; 8. ☒ formal of size: ☒A4 ☐11"

9. **DOMESTIC/INTERNATIONAL** priority is claimed under 35 USC 119(e)/120/365(c) based on the following provisional, nonprovisional and/or PCT international application(s):

Application No.	Filing Date	Application No.	Filing Date
(1)		(2)	
(3)		(4)	
(5)		(6)	

10. **FOREIGN** priority is claimed under 35 USC 119(a)-(d)/365(b) based on filing in EUROPE

Application No.	Filing Date	Application No.	Filing Date
(1) 00310637.4	30 NOVEMBER 2000	(2)	
(3)		(4)	
(5)		☐ See 3rd page for additional priorities	

11. 1 (No.) Certified copy (copies): ☒ attached; ☐ previously filed (date) ______ in U.S. Application No. / filed on ______

12. ☐ This is a reissue of Patent No. ______

13. ☐ See top first page re prior Provisional, National, International application(s) (X box only if info is there and do not complete item 14 or 15.)

14. This application claims benefit of the following prior US application(s), the contents of which are incorporated into this application by this reference:

No. / filed ______
No. / filed ______
No. / filed ______
No. PCT/ / filed ______, which

designated the U.S. and that International Application ☐ was ☐ was not published under PCT Acticle 21(2) in English

15. ☐ See the attached Preliminary Amendment, which amends the specification to claim benefit of the above listed US applications

16. Extension to date: ☐ concurrently filed ☒ not needed ☐ previously filed

17. ☐ Small Entity Status is claimed (**pre**-filing confirmation **required**)

17(a) ☐ Attached: (No.) Small Entity Statement(s). (Since 9/8/00 Small Entity Statement not essential to make claim)

17(b) ☐ See **NONPUBLICATION REQUEST** under Rule 213(a) attached (Pat-258)

18. ☒ Assignee (optional): ASM LITHOGRAPHY B.V.

19. ☒ **Attached: FORM PTO-1449 AND LISTED DOCUMENTS**

20. This application is made by the following named inventor(s) **(Double check instructions for accuracy.):**
(Listing of inventor(s) not a requirement, but list if known)

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21. NOTE: FOR ADDITIONAL INVENTORS, "X" box ☒ and list additional inventors on attached sheet (incorporated by reference)

00909

81468.0284123

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NOTE: File in duplicate with 2 post card receipts (PAT-103) & attachments

REQUEST FOR FILING APPLICATION
Under Rule 53(a), (b)(l) & (d)(l)
(Continued : Additional Inventors)

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J1040 U.S. PTO
09/989700
11/21/01

Bescheinigung | Certificate | Attestation

Die angehefteten Unterlagen stimmen mit der ursprünglich eingereichten Fassung der auf dem nächsten Blatt bezeichneten europäischen Patentanmeldung überein.

The attached documents are exact copies of the European patent application described on the following page, as originally filed.

Les documents fixés à cette attestation sont conformes à la version initialement déposée de la demande de brevet européen spécifiée à la page suivante.

Patentanmeldung Nr. | Patent application No. | Demande de brevet n°

00310637.4

Der Präsident des Europäischen Patentamts;
Im Auftrag

For the President of the European Patent Office

Le Président de l'Office européen des brevets
p.o.

I.L.C. HATTEN-HECKMAN

DEN HAAG, DEN
THE HAGUE, 18/09/01
LA HAYE, LE

EPA/EPO/OEB Form 1014 - 02.91

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Blatt 2 der Bescheinigung
Sheet 2 of the certificate
Page 2 de l'attestation

Anmeldung Nr.:
Application no.: 00310637.4
Demande n°:

Anmeldetag:
Date of filing: 30/11/00
Date de dépôt:

Anmelder:
Applicant(s):
Demandeur(s):
ASM LITHOGRAPHY B.V.
5503 LA Veldhoven
NETHERLANDS

Bezeichnung der Erfindung:
Title of the invention:
Titre de l'invention:
Lithography apparatus with movable cable support

In Anspruch genommene Prioriät(en) / Priority(ies) claimed / Priorité(s) revendiquée(s)

Staat: State: Pays:	Tag: Date: Date:	Aktenzeichen: File no. Numéro de dépôt:

Internationale Patentklassifikation:
International Patent classification:
Classification internationale des brevets:
G03F7/20

Am Anmeldetag benannte Vertragstaaten:
Contracting states designated at date of filing: AT/BE/CH/CY/DE/DK/ES/FI/FR/GB/GR/IE/IT/LI/LU/MC/NL/PT/SE/TR
Etats contractants désignés lors du depôt:

Bemerkungen:
Remarks:
Remarques:
See for original title of the application page 1 of the description.

such "multiple stage" devices the additional tables may be used in parallel, or preparatory steps may be carried out on one or more stages while one or more other stages are being used for exposures. Twin stage lithographic apparatus are described in International Patent Applications WO 98/28665 and WO 98/40791, for example.

Lithographic projection apparatus can be used, for example, in the manufacture of integrated circuits (ICs). In such a case, the mask (reticle) may contain a circuit pattern corresponding to an individual layer of the IC, and this pattern can be imaged onto a target portion (comprising one or more dies or part of a die) on a substrate (silicon wafer) which has been coated with a layer of radiation-sensitive material (resist). In general, a single wafer will contain a whole network of adjacent targeted portions which are successively irradiated via the reticle, one at a time. In one type of lithographic projection apparatus, each target portion is irradiated by exposing the entire reticle pattern onto the target portion in one go; such an apparatus is commonly referred to as a wafer stepper. In an alternative apparatus - which is commonly referred to as a step-and-scan apparatus - each target portion is irradiated by progressively scanning the mask pattern under the projection beam in a given reference direction (the "scanning" direction) while synchronously scanning the substrate table parallel or anti-parallel to this direction; since, in general, the projection system will have a magnification factor M (generally < 1), the speed v at which the substrate table is scanned will be a factor M times that at which the mask table is scanned. More information with regard to lithographic devices as here described can be gleaned from International Patent Application WO 97/33205.

In a lithographic apparatus, the size of features that can be imaged onto the substrate is limited by the wavelength of the projection radiation. To produce integrated circuits with a higher density of devices and hence higher operating speeds, it is desirable to be able to image smaller features. Whilst most current lithographic projection apparatus employ ultraviolet light generated by mercury lamps or excimer lasers, it has been proposed to use shorter wavelength radiation of around 13nm. Such radiation is termed extreme ultraviolet (EUV) or soft x-ray, and possible sources include laser produced plasma sources, discharge plasma

MOVEABLE CABLE SUPPORT FOR LITHOGRAPHY APPARATUS

The present invention relates to a device used in conjunction with conduits for providing utilities such as power, control signals and gases through cables, hoses or pipes to a substrate table under vacuum. More particularly, the invention relates to the incorporation of such devices in lithographic projection apparatus comprising:

an illumination system for supplying a projection beam of radiation;

a first object table for holding a mask, and connected to a first positioning means for positioning the first object table;

a second object table for holding a substrate, and connected to a second positioning means for positioning the second object table;

a vacuum chamber enclosing at least one of said first and second object tables; and

a projection system for imaging an irradiated portion of the mask onto a target portion of the substrate; wherein

utilities are provided through conduits to said object tables in the vacuum chamber.

For the sake of simplicity, the projection system may hereinafter be referred to as the "lens"; however, this term should be broadly interpreted as encompassing various types of projection system, including refractive optics, reflective optics, catadioptric systems, and charged particle optics, for example. The radiation system may also include elements operating according to any of these principles for directing, shaping or controlling the projection beam of radiation, and such elements may also be referred to below, collectively or singularly, as a "lens". In addition, the first and second object tables may be referred to as the "mask table" and the "substrate table", respectively. Further, the lithographic apparatus may be of a type having two or more mask tables and/or two or more substrate tables. In

sources or synchrotron radiation from electron storage rings. An outline design of a lithographic projection apparatus using synchrotron radiation is described in "Synchrotron radiation sources and condensers for projection x-ray lithography", JB Murphy et al, Applied Optics Vol. 32 No. 24 pp 6920-6929 (1993).

Other proposed radiation types include electron beams and ion beams. These types of beam share with EUV the requirement that the beam path, including the mask, substrate and optical components, be kept in a high vacuum. This is to prevent absorption and/or scattering of the beam, whereby a total pressure of less than about 10^{-6} millibar is typically necessary for such charged particle beams. Substrates can be contaminated, and optical elements for EUV radiation can be spoiled, by the deposition of carbon layers on their surface, which imposes the additional requirement that hydrocarbon partial pressures should generally be kept below 10^{-8} or 10^{-9} millibar. Otherwise, for apparatus using EUV radiation, the total vacuum pressure need only be 10^{-3} or 10^{-4} mbar, which would typically be considered a rough vacuum.

Further information with regard to the use of electron beams in lithography can be gleaned, for example, from US 5,079,122 and US 5,260,151, as well as from EP-A-0 965 888.

Working in such a high vacuum imposes quite onerous conditions on the components that must be put into the vacuum. For components inside the chamber, materials that minimise or eliminate contaminant and total outgassing, i.e. both outgassing from the materials themselves and from gases adsorbed on their surfaces, should be used. It would be very desirable to be able to reduce or circumvent such restrictions.

Current lithography apparatus are designed for use in clean room environments and therefore some steps have conventionally been taken to reduce possible sources of contamination of wafers that are processed by the apparatus. However, conventional designs of substrate, mask and transfer stages are very complicated and employ large numbers of components for sensor and drive arrangements. Such stages also need to be provided with large numbers of signal and control cables and other utilities.

It is an object of the present invention to provide a lithographic apparatus with substantially reduced problems due to out-gassing of materials in the vacuum chamber.

According to the present invention there is provided a lithographic projection apparatus comprising:

an illumination system for supplying a projection beam of radiation;

a first object table for holding a mask, and connected to a first positioning means for positioning the first object table;

a second object table for holding a substrate, and connected to a second positioning means for positioning the second object table;

a vacuum chamber enclosing at least one of said first and second object tables; and

a projection system for imaging an irradiated portion of the mask onto a target portion of the substrate;

wherein utilities are provided through conduits to at least one moveable component selected from a group including said object tables, associated motors and sensors in said vacuum chamber; said apparatus characterised in that it further comprises:

a conduit conduct for said at least one moveable component in said vacuum chamber for shielding said conduits from said vacuum, said conduit conduct having at least the same number of degrees of freedom as its associated component.

The term "conduit" as here employed refers to the "umbilical cord" which generally connects at least one of the movable tables to the outside frame (e.g. a metrology frame) and which carries such items as power cords, signal carriers, gas tubes (e.g. for supplying gas to a gas bearing in the table), coolant tubes, etc. Moveable components inside the vacuum chamber including the mask table and/or the substrate table and/or associated motors and/or sensors may be connected to an outside frame in this manner (using a distinct conduit conduct for each component).

It has been found that for the typically desired degree of movement required by the object holders, conduits need to be made of plastics materials such that they are flexible enough. These types of materials often are unfortunately deleterious to the vacuum in the vacuum chamber as described above. There are plastics better suited for vacuum applications (for example teflon) but the large number of cables and lines which are required to be lead through the vacuum, if unprotected, present a large surface area to outgassing. Furthermore, the risk of leaks from unshielded conduits makes their use impractical.

By use of the closed conduit conduct(s), utilities are provided to the object tables without deleterious effects to the vacuum in the vacuum chamber. Furthermore, the lifetime of the material of the conduits is not affected because they are not exposed to the high vacuum but to conditions chosen by the machine manufacturer, for example, a rough vacuum.

According to a second aspect of the present invention there is provided a device manufacturing method using a lithographic apparatus comprising:

an illumination system for supplying a projection beam of radiation;

a first object table for holding a mask, and connected to a first positioning means for positioning the first object table;

a second object table for holding a substrate, and connected to second positioning means for positioning the second object table;

a vacuum chamber enclosing at least one of said first and second object tables, and

a projection system for imaging an irradiated portion of the mask onto a target portion of the substrate;

wherein utilities are provided through conduits to at least one moveable component selected from a group including said object tables, associated motors and sensors in said vacuum chamber; the method comprising the steps of:

providing a substrate which is at least partly covered by a layer of radiation-sensitive material;

providing a mask containing a pattern;

using a projection beam of radiation to project an image of at least part of the mask pattern onto a target portion of the layer of radiation-sensitive material; wherein

during the step of projecting an image, the substrate is mounted on said second object table; the method characterised in that said apparatus further comprises:

a conduit conduct for said at least one moveable component in said vacuum chamber for shielding said conduits from said vacuum, said conduit conducts each having at least the same number of degrees of freedom as their associated component.

In a manufacturing process using a lithographic projection apparatus according to the invention a pattern in a mask is imaged onto a substrate which is at least partially covered by a layer of radiation-sensitive material (resist). Prior to this imaging step, the substrate may undergo various procedures, such as priming, resist coating and a soft bake. After exposure, the substrate may be subjected to other procedures, such as a post-exposure bake (PEB), development, a hard bake and measurement/inspection of the imaged features. This array of procedures is used as a basis to pattern an individual layer of a device, e.g. an IC. Such a patterned layer may then undergo various processes such as etching, ion-implantation (doping) metallisation, oxidation, chemo-mechanical polishing, etc., all intended to finish off an individual layer. If several layers are required, then the whole procedure, or a variant thereof, will have to be repeated for each new layer. Eventually, an array of devices will be present on the substrate (wafer). These devices are then separated from one another by a technique such as dicing or sawing, whence the individual devices can be mounted on a carrier, connected to pins, etc. Further information regarding such processes can be obtained, for example, from the book "Microchip Fabrication: A Practical Guide to Semiconductor Processing", Third Edition, by Peter van Zant, McGraw Hill Publishing Co., 1997, ISBN 0-07-067250-4.

Although specific reference may be made in this text to the use of the apparatus according to the invention in the manufacture of ICs, it should be explicitly understood that such an apparatus has many other possible applications. For example, it may be employed in the manufacture of integrated optical systems, guidance and detection patterns for magnetic domain memories, liquid-crystal display panels, thin-film magnetic heads, etc. The skilled artisan will appreciate that, in the context of such alternative applications, any use of the terms "reticle", "wafer" or "die" in this text should be considered as being replaced by the more general terms "mask", "substrate" and "target portion", respectively.

The present invention and its attendant advantages will be described below with reference to exemplary embodiments and the accompanying schematic drawings, in which:

Fig. 1 depicts a lithographic projection apparatus according to a first embodiment of the invention;

Fig. 2 is a schematic plan view showing a conduit conduct according to the first embodiment;

Fig. 3 is a schematic showing the position of first and second conduit conducts according to the first embodiment in normal operation;

Fig. 4 is a schematic showing the positions of first and second conduit conducts according to the first embodiment during initial swap movements;

Fig. 5 is a schematic showing the positions of first and second conduit conducts according to the first embodiment during swap;

Fig. 6 is a schematic showing the positions of the first and second conduit conducts according to the first embodiment during normal operation;

Fig. 7 is a schematic showing a conduit conduct of the second embodiment;

Fig. 8 is a schematic showing a conduit conduct of the third embodiment;

Fig. 9 is a schematic showing a conduit conduct of the fourth embodiment;

Fig. 10a is a schematic sectional view showing a joint of the fifth embodiment;

Fig. 10b is a variation on the joint of the fifth embodiment;

Fig. 11 is a schematic showing an inner member of a joint of a sixth embodiment;

Fig. 12 is a schematic plan view showing the joint of the sixth embodiment;

Fig. 13 is a cross-sectional view of a differential gas bearing according to a seventh embodiment of the invention;

Fig. 14 is a cross-sectional view of the substrate table and forearm of the positioning means of an eighth embodiment of the lithographic projection apparatus according to the invention;

Fig. 15 is a cross-sectional view of the substrate table and forearm of the positioning means of a ninth embodiment of the lithographic projection apparatus according to the invention; and

Fig. 16 is a cross-sectional view of the substrate table and forearm of the positioning means of a tenth embodiment of the lithographic projection apparatus according to the invention.

In the various drawings, like parts are indicated by like references.

Embodiment 1

Figure 1 schematically depicts a lithographic projection apparatus 1 according to the invention. The apparatus comprises:

- a radiation system LA, IL for supplying a projection beam PB of radiation (e.g. UV or EUV radiation, electrons or ions);
- a first object table (mask table) MT provided with a first object (mask) holder for holding a mask MA (e.g. a reticle), and connected to first positioning means PM for accurately positioning the mask with respect to item PL;
- a second object table (substrate table) W2T provided with a second object (substrate) holder for holding a substrate W2 (e.g. a resist-coated silicon wafer), and connected to second positioning means P2W for accurately positioning the substrate with respect to item PL;
- a third object table (substrate table) W3T provided with a third object (substrate) holder for holding a substrate W3 (e.g. a resist-coated silicon wafer), and connected to third positioning means P3W for accurately positioning the substrate with respect to item PL; and

- a projection system ("lens") PL (e.g. a refractive or catadioptric system, a mirror group or an array of field deflectors) for imaging an irradiated portion of the mask MA onto a target portion C of the substrate W.

The radiation system comprises a source LA which produces a beam of radiation (e.g. an undulator or wiggler provided around the path of an electron beam in a storage ring or synchrotron, a plasma source, an electron or ion beam source, a mercury lamp or a laser). This beam is caused to traverse various optical components included in illumination system IL so that the resultant beam PB has a desired shape and intensity distribution in its cross-section.

The beam PB subsequently impinges upon the mask MA which is held in a mask holder on a mask table MT. Having been selectively reflected (or transmitted) by the mask MA, the beam PB passes through the "lens" PL, which focuses the beam PB onto a target portion C of the substrate W2, W3. With the aid of the positioning means P2W, P3W and interferometric displacement measuring means IF, the substrate table W2T, W3T can be moved accurately, e.g. so as to position different target portions C in the path of the beam PB. Similarly, the positioning means PM and interferometric displacement measuring means IF can be used to accurately position the mask MA with respect to the path of the beam PB, e.g. after mechanical retrieval of the mask MA from a mask library or during a scanning motion. In the prior art, movement of the object tables MT, W2T is generally realised with the aid of a long-stroke module (course positioning) and a short-stroke module (fine positioning), which are not explicitly depicted in Figure 1.

The depicted apparatus can be used in two different modes:

- In step mode, the mask table MT is kept essentially stationary, and an entire mask image is projected in one go (i.e. a single "flash") onto a target portion C. The substrate table W2T, is then shifted in the X and/or Y directions so that a different target portion C can be irradiated by the beam PB;
- In scan mode, essentially the same scenario applies, except that a given target portion C is not exposed in a single "flash". Instead, the mask table MT is movable in a given direction (the so-called "scan direction", e.g. the Y

direction) with a speed v, so that the projection beam PB is caused to scan over a mask image; concurrently, the substrate table W2T, is simultaneously moved in the same or opposite direction at a speed $V = Mv$, in which M is the magnification of the lens PL (e.g., $M = 1/4$ or $1/5$). In this manner, a relatively large target portion C can be exposed, without having to compromise on resolution.

In a lithographic projection apparatus according to the present invention, at least one of first and second object tables are provided in a vacuum chamber 20.

Much equipment is associated with an object table, such as alignment sensors, air bearings with differential vacuum seals, positioning motors and actuators which require utilities such as power, control signals, vacuum and gasses and supply utilities such as measurement signals and further control signals. These utilities are supplied by conduits such as, for example, hoses, pipes, electrical cables etc. Although the conduit conduct of the present invention is described in relation to an embodiment with two object tables, it is equally applicable to a lithographic projection apparatus with only a single object table or to other moveable components in the vacuum chamber.

Contamination control is a major issue. A small number of hydrocarbon (C_xH_y) mono-layers on the mirrors, for instance, will lead to an unallowable reduction in the reflection efficiency of these mirrors. In a "clean" vacuum environment, materials like plastics and elastomers continuously outgas and hollow sections of constructions like screw joints tend to increase gas load (mainly water and hydrocarbons) and contamination via virtual leakage.

By shielding the conduits providing utilities to the object tables using conduit conducts, which each have at least the same number of degrees of freedom as their associated object tables, it is possible for the conduits to be under atmospheric conditions along substantially their whole length. This results in an increased lifetime of the materials of the conduits and also helps meet the vacuum requirements by reducing the amount of hydrocarbons exposed in the vacuum chamber 20 and also helps reducing the risks in case of the rupture of a coolant line. The number of joints (both rotational and translational) and arm portions can be varied depending on the required number of degrees of freedom of

movement of the respective moveable component. For example the conduit conduct may only be required to have one arm which is not necessarily rotatable about a joint.

Figure 2 shows only one conduit conduct 100 connecting conduits 24 from outside of the vacuum chamber 20 to the object table W2T. The first embodiment of the present invention has two such object tables. The conduits 24 pass through a side wall 21 of the vacuum chamber 20 at an input 12 to the conduit conduct 100 which comprises three hollow and elongate arm portions 107, 110, 120. Translation arm portion 107 is translatable relative to the vacuum chamber side wall 21. This is accomplished by arranging the outer surface of translating arm portion 107 to be in sliding contact with the inside surface of a receiving translation arm portion 109. A differential vacuum seal 108a and air, or gas, bearing 108b provided between those two surfaces allows for low friction movement between the arm portions 107, 109 whilst still maintaining the vacuum in the vacuum chamber 20. A differential vacuum seal and air, or gas, bearing assembly 108a, 108b is described in detail in the seventh embodiment.

First arm portion 110 is joined at one end to translating arm portion 107 via second joint 105 and is rotatable about second joint 105. At the other end, first arm portion 110 is rotatably joined to an end of second arm portion 120 via first joint 115. The object table W2T is joined to second arm portion 120 at the other end. The joints 105, 115 and arm portions 107, 110, 120 are airtight and therefore in this way the conduits 24 are provided to the object table W2T without being exposed to the vacuum in the vacuum chamber 20 and, if required, may be provided under manufacturer chosen conditions. If translation joints are used, it is preferable to provide a rough vacuum in the conduit conduct 100 such that the forces necessary to activate the joint are not excessively large (if the conduit is under atmospheric pressure, the vacuum in the vacuum chamber generates a force which acts to extend the translation joint).

The conduit conducts 100 may comprise torque motors in the joints 105, 115 such that the conduit conduct 100 can position the object table W2T. It is also possible that the conduit conduct 100 moves under the influence of the positioning means of the object table W2T. That is the conduit conducts 100 can either be

passive in that it does not comprise any driving motors and only moves under the influence of the object table W2T, or it can be active and have its own motors to move with the object table. In some embodiments the conduit conducts 100 themselves can be used to position the object table W2T.

It is advantageous in a lithographic apparatus to have two object tables for holding substrates which can be driven independently. In this way it is possible to be measuring or performing some other function such as unloading a previously exposed wafer and loading a new wafer in a measuring area at the same time as exposing a different, previously unexposed wafer, in the exposure area. The exchange of wafer tables between the measuring and exposure areas is called "swap". In the first embodiment, a third object table, designated W3T in Figure 1 as well as a second object table W2T is provided for this purpose.

It is advantageous to reduce the size of the apparatus. The first embodiment achieves this through the arrangement of the first and second conduit conducts associated with their respective second and third object tables. Furthermore, the arrangement reduces the amount of rotation of the first and second joints required to move the substrate table in the exposure and measuring areas and to transfer the substrate table from the exposure area to the measuring area or visa versa. This reduces stresses on the conduits and subsequently increases apparatus lifetime.

In the lithography apparatus of the first embodiment of the present invention, whilst one of the second or third object tables is in an exposure area in which the wafer held by the respective object table is irradiated, the other one of the second and third object tables is in a measuring area where the wafer is measured, loaded and offloaded.

Figure 3 shows in plan the second object table W2T and the third object table W3T positioned in the measuring area 300 and exposure area 200, respectively. First conduit conduct 100 provides utilities to second object table W2T and second conduit conduct 150 provides utilities to the third object table W3T.

First and second conduit conducts 100, 150 are identical and comprise a first arm portion 110, 160 and a second arm portion 120, 170 which are rotatably connected at first joint 115, 165. The first arm portions of the first and second

conduit conducts 100, 150 are rotatable relative to the exposure area 200 (first working zone), the measuring area 300 (second working zone) and the lithographic apparatus around second joints 105, 155. As shown in Figure 3 when the second object table is in the measuring position, the second joint 105 of the first conduit conduct 100 rotates around a second position 102. In the second position the second object table is positionable within the measuring area 300. In contrast, when the third object table W3T is positioned within the exposure area 200, the second joint 155 of the second conduit conduct 150 is in a first position 151. The second position 102 of the first conduit conduct 100 is generally equidistant from the exposure area 200 and the measuring area 300 and the first position 151 of the second conduit conduct 150 is generally equidistant from the exposure area 200 and measuring area 300. The second joints 105, 155 are translatable from the first to second positions 101,102,151,152 and visa versa through translation joints which comprise translating arm portions 107,157 attached to second joints 105, 155 which slide in receiving arm portions 109, 159 to move the first joints from the first to second positions 101, 102, 151, 152. The sliding seal is maintained by differential vacuum seals 108a, 158a and air bearings 108b, 158b.

A “swap” operation, in which the second object table 130 moves from one of the exposure 200 and measuring 300 areas to the other area and the third object table W3T moves in the opposite direction, is depicted schematically in Figures 4 and 5. Although Figures 4 and 5 illustrate one combination of movements which result in so-called “swap”, the sequence of movements could be in a different order.

As is shown in Figure 4, if swap is to be initiated, the first step is the translation of the second joint 105, 155 of both first and second conduit conducts. In the case of the second object table, the second joint 105 of the first conduit conduct 100 moves from its second position 102 to a first position 101 which is positioned closer to the exposure area 200 than to the measuring area 300. During this operation, the second object table remains substantially within the measuring area 300 and it may move within that area. In the case of the third object table, the second joint 155 of the second conduit conduct 150 moves from the first position

151 to a second position 152 whilst the third object table 180 remains substantially on the exposure area 200.

The next stage during swap is depicted in Figure 5 in which the second and third object tables are moved towards the second joint 105, 155 of their respective conduit conducts 100, 150. In this position the second and third object tables are substantially between the exposure area 200 and measuring area 300.

Finally, as is shown in Figure 6, for exposure of the wafer held on the second object table W2T, the second joint 105 of the first conduit conduct 100 is located at the first position 101 of the first conduit conduct 100. For measuring of the wafer on the third object table W3T, the second joint 155 of the second conduit conduct 150 is positioned at the second position 152 rather than the first position 151.

The joints 105, 115, 155, 165 of the conduit conducts 100, 150 have an angular range of motion of less than about 100° and preferably less than about 90°. This can be arranged by the correct positioning of the first 101, 151 and second 102, 152 positions and the sizes of the exposure and measuring areas 200, 300. Furthermore, by allowing translation of the second joint 105, 155, the size of the conduit conducts and the exposure and measurement areas can be minimised.

The second and third object tables are preferably rotatable relative to the second arm portion of their respective conduit conducts. Any number of arm portions, rotational joint and translatable joints may make up a conduit conduct. The precise arrangement will depend on the requirements and the number of degrees of freedom of the components with which they are associated. In the following embodiments variations are described as well as specific examples of the various components which make up the conduit conducts. It will be apparent to the skilled person that other variations not described here are also possible.

Embodiment 2

Figure 7 shows a conduit conduct 100 according to a second embodiment which maybe is the same as the first embodiment save as described below. In the second embodiment the second and third object tables W2T, W3T are rotatably mounted to a main rotating joint 103. In order to perform swap, the main

rotating joint 103 is rotated by 180° such that first and second object tables W2T, W3T swap positions illustrated in Figure 7. Positioning in the exposure and measurement areas is accomplished through rotation of positioning joints 125, 175 to rotate the object tables W2T, W3T relative to main rotating joint 103 and through extension and retraction of translating arm portion 107, 157 out of and into receiving arm portion 109, 159. As in the first embodiment, the moving surfaces of the translating arm portions are preferably sealed using differential vacuum seals and air bearing assemblies 108, 158.

Embodiment 3

Figure 8 shows a conduit conduct 100 according to a third embodiment which may be the same as the first embodiment save as described below. Figure 8 only shows a single conduit conduct 100 and object table W2T. This embodiment of a conduit conduct can equally well be applied to the case where a third object table W3T is present and swap between the measurement area 300 and the exposure area 200 is necessary. In the third embodiment, the conduit conduct 100 has no rotational joints. For manoeuvrability the conduit conduct 100 is provided with two translatable joints allowing extension/retraction in substantially orthogonal directions. The conduit conduct 100 is the same as that in the first embodiment except that rotational first joint 115 is replaced by a translatable joint 118 and rotational second joint 105 is replaced by a fixed portion joining translating arm portion 107 at 90° to first arm portion 110. Translatable joint 118 is of the same structure as the translatable joint in the first embodiment and is sealed with a differential vacuum seal and air, or gas, bearing assembly 118.

Embodiment 4

Figure 9 shows a conduit conduct 100 according to a fourth embodiment which maybe the same as the first embodiment save as described below. In this embodiment the object table W2T is attached to the end of translating arm portion 107. Receiving arm portion 109 protrudes from a translatable plate 122 which is translatable (in a direction substantially orthogonal to the direction in which translating arm portion 107 is translatable) relative to the vacuum chamber side

wall 21. Translatable plate 122 slides relative to vacuum side wall 21 on an air bearing and differential vacuum seal arrangement 121.

Embodiment 5

Figure 10a shows in detail a joint 115 of the conduit conduct 100 of the fifth embodiment. Other bearing types are also possible and this description is given only as an example. In the schematic illustration, the joint 115 forms the hinge between the first arm portion 110 and the second arm portion 120. The joint may alternatively form the hinging mechanism between an arm portion 110, 120 and the vacuum chamber wall 21 or an object table W2T, W3T. A passageway through the joint 115, the first arm portion 110, and second arm portion 120 allows conduits 24 to pass through the conduit conduct 100. The joint 115 comprises a first member 26 with a cylindrical outer surface and a second member 28 with a cylindrical inner surface. The second member 28 co-operates with the first member 26 and is rotatable co-axially with and relative to the first member 26. An air bearing 20 and differential vacuum seal 22 is provided between opposing surfaces of first and second members 26, 28.

An alternative arrangement is shown in Figure 10b in which the first and second members 26, 28 have flanges 27, 29 attached at their ends. The surfaces of the flanges oppose each other and an air bearing 20 and vacuum differential seal 22 are provided between the opposing surfaces.

The first and second members 26, 28 are formed as hollow open ended pipes such that conduits 24 may pass through the centre of the members. The first and second members 26, 28 are connected to the first and second arm portions 110, 120 such that conduits can pass from the first arm portion 110 through the joint 115 and into the second arm portion 120 with the only joining surfaces between the two arm portions being sealed by a vacuum differential seal. This allows for free rotation of arm portions 110 and 120 relative to each other whilst ensuring that the conduits 24 inside the conduit conducts 100 are not exposed to the vacuum. Differential vacuum seals comprise at least one passage exposed to a low pressure source. Optionally, a differential vacuum seal can comprise several passages each

exposed to successively lower pressure sources. A differential vacuum seal is described in the seventh embodiment.

Embodiment 6

Figures 11 and 12 show a joint 115 according to a sixth embodiment of the invention which is the same as the first embodiment save as described below. Joint 115 is provided such that first and second arm portions 110, 120 are substantially in the same plane. The joint may alternatively form the hinging mechanism between an arm portion 110, 120 and the vacuum chamber wall 21 or an object table W2T, W3T. In this embodiment, an inner member 32 with an at least partially cylindrical outer surface is provided at an end of a first hollow arm portion 110. As can be seen from Figure 12, a second arm portion 120 is provided with an outer member 38 which has an at least partially cylindrical inner surface which co-operates with the outer surface of said inner member 32. The inner surface of the inner member 32 has a first opening 34 leading into said first arm portion 110 through which conduits 24 pass and the inner surface of the outer member 38 has a second opening 40 through which conduits 24 can pass into said second arm portion 120. An air bearing 20 and differential vacuum seal 22 are provided around openings 34 and 40 in between opposing surfaces of members 32 and 28. The inner member 32 is closed at the top and bottom of the cylindrical surface such that the inside of the cylinder is not exposed to the vacuum. The sizes of the first and second openings 34, 40 in the inner member are dimensioned such that at any angle of desired rotation the first opening 34 and second opening 40 align such that conduits 24 can pass through said first arm portion 110 into said second arm portion 120. Because this configuration allows first and second arm portions 110, 120 to be in substantially the same (horizontal) plane, the conduits 24 are only bent and not twisted relative to each other as the arm portions 110, 120 rotate about the joint 115. This is advantageous because the lifetime of the conduits 24 can be increased by reducing twisting and/or rubbing together.

Embodiment 7

An example of a gas bearing ("air bearing") and differential vacuum seal

which can be used in the embodiments described above will now be described referring to Figure 13. Figure 13 is a cross-section through a differential gas-bearing 108, showing part of a supporting member, e.g. receiving translatable arm portion 109, and a supported member, e.g. translating arm portion 107. Gas bearing 108 holds the translating arm portion 107 off the receiving arm portion by a constant gap, g, of 5 μm, for example. For such a gap, the surface 109b of the receiving arm portion 109 in the vicinity of the bearing, and the surface 107b of the translating arm portion 107 over the area of travel of the bearing, must be finished to an RMS surface roughness of less than 0.8 μm, though they need not be flatter than 0.4 μm RMS surface roughness. This can readily be achieved with known mechanical polishing techniques. In some applications a gap in the range of from 5 μm to 10 μm may be appropriate and the surfaces need not be finished to such high tolerances. Clean air (or other gas, e.g. N_2) is supplied continually through gas feed 211 at a pressure of several atmospheres to generate a high pressure region 214. The supplied air will flow towards a compartment M and also the vacuum chamber 20, where its presence would, of course, be undesirable. An escape path to atmospheric pressure is provided via groove 212. To prevent further the air that forms the air bearing becoming an unacceptable leak into the vacuum chamber 20, it is pumped away via vacuum conduit 213. If desired, the escape path 212 may also be pumped. In this way, the residual leakage, l, into the vacuum chamber 20 can be kept within acceptable levels.

Embodiment 8

An eighth embodiment of the invention is shown schematically in Figure 14. This embodiment may be the same as the first embodiment save as described below. Although only one conduit conduct and object table are shown, the same arrangement can be used for both second and third object tables with respective first and second conduit conducts of the present invention as well as the first object table. Like references are used where possible.

In the eighth embodiment, the object tables are connected to positioning means which are independent of the conduit conduct. The conduit conduct may or may not include, for example, torque motors in the second joint 105 and first

joint 115. The second arm portion 120 of the conduit conduct is attached to the object table W2T with bellows 650 through which conduits 24 pass. In this way, utilities are provided from second joint 105 to object table W2T.

Object table W2T is connected to positioning means comprising a first or long stroke module 620 and a second or short stroke module 630. Long stroke module 620 has a first range of motion relative to a frame of reference and short stroke module 630 is supported by the long stroke module 620 and has a second range of motion, the second range of motion being smaller than the first range of motion.

The area over which long stroke module 620 can move is designated BP. In this embodiment the area is provided with a planar motor magnet array in base plate BP. Exposure area 200 and measuring area 300 in this embodiment as shown in Figure 3 also have a planar motor magnet array and areas outside of the exposure and measuring areas, especially between the two areas, are also provided with a planar motor magnet array as necessary.

The positioning means for the object table in the eighth embodiment of the present invention comprises planar motor coils 625 in the long stroke module 620. Positioning of the short stroke module 630 on the long stroke module 620 is accomplished by use of Lorentz-force motors 660 with 6 degrees of freedom. The planar motor and Lorentz-force motors are only schematically depicted in Figure 14.

Embodiment 9

A ninth embodiment of the invention is shown schematically in Figure 15. This embodiment may be the same as the first embodiment save as described below. In Figure 15, only a part of the second arm portion of the conduit conduct is illustrated. A tray 700 for coarse positioning of the object table is attached to the end of the second arm portion 120 of the conduit conduct which is positionable through use of planar motor coils 705 and a planar motor magnetic array incorporated in base plate BP. Conduits are supplied to a first, long stroke module 620 of the positioning means connected to object table W2T, through bellows 650. The positioning means for the long stroke module in this

embodiment of the present invention comprises planar motor coils 625. As in the eighth embodiment a short stroke module 630, positioned on top of the long stroke module, is positioned by Lorentz-force motors 660 with 6 degrees of freedom.

Embodiment 10

A tenth embodiment of the present invention is illustrated schematically in Figure 16. This embodiment may be the same as the first embodiment save as described below. In this embodiment the position of a tray 700 which carries the object table is determined by the conduit conduct whose first and second joints are driven by torque motors, for example. The weight of the tray 700 is supported on surface BP by air bearings with differential vacuum seals 815. A bellows 830 and leaf spring 835 arrangement in the arm portion 120 of the conduit conduct near the tray 700 allows a small amount of relative movement between the conduit conduct and the tray. Major positional movements are carried out by the torque motors in the conduit conduct joints but medium sized movements are carried out by movement of first module 620 and minor movements are carried out by movement of second module 630. First module 620 is moved relative to tray 700 with the use of 6 degree of freedom medium stroke Lorentz-force actuators. Movement between the first module 620 and the second module 630 is also accomplished using a 6 degrees of freedom Lorentz-force actuator. Gravity compensators may be employed with Lorentz-force actuators to supply a force counteracting gravity for relieving the Lorentz-force motors from delivering such a force.

The invention is described above in relation to preferred embodiments; however it will be appreciated that the invention is not limited by the above description. In particular, the invention has been described above in relation to the wafer stage of a lithographic apparatus that is accommodated in a vacuum

chamber. However, it will readily be appreciated that the present invention is equally applicable to mask tables.

Further, the swap mechanisms disclosed may also be employed in a non-vacuum environment where utilities are provided to the object tables such that those utilities need not be disconnected during swap.

CLAIMS

1. A lithographic projection apparatus comprising:

an illumination system for supplying a projection beam of radiation;

a first object table for holding a mask, and connected to a first positioning means for positioning the first object table;

a second object table for holding a substrate, and connected to a second positioning means for positioning the second object table;

a vacuum chamber enclosing at least one of said first and second object tables; and

a projection system for imaging an irradiated portion of the mask onto a target portion of the substrate;

wherein utilities are provided through conduits to at least one moveable component selected from a group including said object tables, associated motors and sensors in said vacuum chamber; said apparatus characterised in that it further comprises:

a conduit conduct for said at least one moveable component in said vacuum chamber for shielding said conduits from said vacuum, said conduit conduct having at least the same number of degrees of freedom as its associated component.

2. A lithographic projection apparatus according to claim 1, wherein said conduit conduct has at least two joints.

3. A lithographic projection apparatus according to claim 1 or 2, wherein said conduit conduct comprises at least one hollow elongate arm portion.

4. A lithographic projection apparatus according to claim 3, wherein one of said at least one hollow elongate arm portion is translatable along its elongate direction relative to another structure at a translation joint.

5. A lithographic projection apparatus according to claim 4, wherein said other structure is a side wall of said vacuum chamber.

6. A lithographic projection apparatus according to claim 4, wherein said other structure is a second one of said at least one hollow elongate arm portion.

7. A lithographic projection apparatus according to any one of claims 3 to 6, wherein said at least one arm portion is hinged for rotation about a rotation joint at least at one end.

8. A lithographic projection apparatus according to claim 7, wherein said arm portion is hinged with a constant volume rotational joint.

9. A lithographic projection apparatus according to any one of claims 4 to 8, wherein moving co-operating surfaces of said joint are furnished with gas bearings and differential vacuum seals.

10. A lithographic projection apparatus according to claim 7, wherein said joint comprises a first member with an at least partly cylindrical inner surface co-operating with and at least partially surrounded by an at least partly cylindrical outer surface of a second member, wherein one of said first and second members is attached to one end of said arm portion.

11. A lithographic projection apparatus according to claim 10, wherein said second member is rotatable co-axially with and relative to said first member.

12. A lithographic projection apparatus according to claim 10 or 11, wherein a first hole in said inner cylindrical surface co-operates with a second hole in said outer cylindrical surface to allow the passage of conduits from said first member, through said first and second holes, into said second member.

13. A lithographic projection apparatus according to any one of claims 10 to 12,

wherein said first and second members are in substantially the same horizontal plane.

14. A lithographic projection apparatus according to claim 10 or 11, wherein said first and second members are pipes with open ends to allow the passage of conduits therethrough.

15. A lithographic projection apparatus according to claim 14, wherein one of said first and second members is attached at an end of said at least one arm portion with the axis of the pipe substantially perpendicular to the elongate direction of said arm portion.

16. A lithographic projection apparatus according to any one of claims 10 to 15, wherein said first member is attached to a first hollow elongate arm portion and said second member is attached to a second hollow elongate member.

17. A lithographic projection apparatus according to any one of claims 10 to 16, wherein one of said first and second members are attached to a first hollow elongate arm portion and the other of said first and second members is attached to said respective movable component.

18. A lithographic projection apparatus according to any one of claims 3 to 17, wherein said at least one hollow elongate arm portion is connected to a translatable plate, said translatable plate being translatable relative to and covering an opening in a side wall of said vacuum chamber forming a translatable joint, wherein moving co-operating surfaces of said translatable joint are furnished with gas bearings and differential vacuum seals.

19. A lithographic projection apparatus according to claim 1, further comprising a third object table for holding a substrate, and connected to a third positioning means for positioning the third object table; and said second and third positioning means being for positioning said respective object tables within a first working

zone and a second working zone; said second and third object tables being enclosed in said vacuum chamber and being provided with utilities through conduits; first and second conduit conducts being provided for said respective second and third object tables.

20. A lithographic projection apparatus according to claim 19, wherein said first and second conduit conducts each comprise a first hollow elongate arm portion.

21. A lithographic projection apparatus according to claim 20, wherein each said first arm portion is rotatably connected to a respective second hollow elongate arm portion at a first joint.

22. A lithographic projection apparatus according to claim 21, wherein said second arm portions are both connected to a main rotating joint.

23. A lithographic projection apparatus according to claim 20 or 21, wherein said first arm portion is connected to a respective one of said second and third object tables.

24. A lithographic projection apparatus according to claim 23, wherein said second arm portion of said first and second conduit conducts is rotatable relative to said projection apparatus around a second joint.

25. A lithographic projection apparatus according to claim 24, wherein said second joint is translatable between a first position, for when said object table is within said first working zone and a second position, for when said object table is within said second working zone.

26. A lithographic projection apparatus according to claim 25, wherein said first and second positions of said first conduit conduct and of said second conduit conduct are all different.

27. A lithographic projection apparatus according to claim 25 or 26, wherein said first and second joints are rotatable in the same plane.

28. A lithographic projection apparatus according to any one of claims 25 to 27, wherein said first position of said first conduit conduct is positioned closer to said first working zone than to said second working zone and said second position of said second conduit conduct is positioned closer to said second working zone than to said first working zone.

29. A lithographic projection apparatus according to any one of claims 25 to 28, wherein said second position of said first conduit conduct is generally equidistant from said first working zone and said second working zone; and said first position of said second conduit is generally equidistant from said first working zone and said second working zone.

30. A lithographic projection apparatus according to any one of claims 25 to 29, wherein if said first conduit conduct is in said first position and said second conduit conduct is in said second position, said first and second substrate tables are moveable from said second working zone to said first working zone and vice versa through rotational movement of said first and second joints only.

31. A device manufacturing method using a lithographic apparatus comprising:

an illumination system for supplying a projection beam of radiation;

a first object table for holding a mask, and connected to a first positioning means for positioning the first object table;

a second object table for holding a substrate, and connected to second positioning means for positioning the second object table;

a vacuum chamber enclosing at least one of said first and second object tables, and

a projection system for imaging an irradiated portion of the mask onto a target portion of the substrate;

wherein utilities are provided through conduits to at least one moveable component selected from a group including said object tables, associated motors and sensors in said vacuum chamber; the method comprising the steps of:

providing a substrate which is at least partly covered by a layer of radiation-sensitive material;

providing a mask containing a pattern;

using a projection beam of radiation to project an image of at least part of the mask pattern onto a target portion of the layer of radiation-sensitive material; wherein

during the step of projecting an image, the substrate is mounted on said second object table; the method characterised in that said apparatus further comprises:

a conduit conduct for said at least one moveable component in said vacuum chamber for shielding said conduits from said vacuum, said conduit conducts each having at least the same number of degrees of freedom as their associated component.

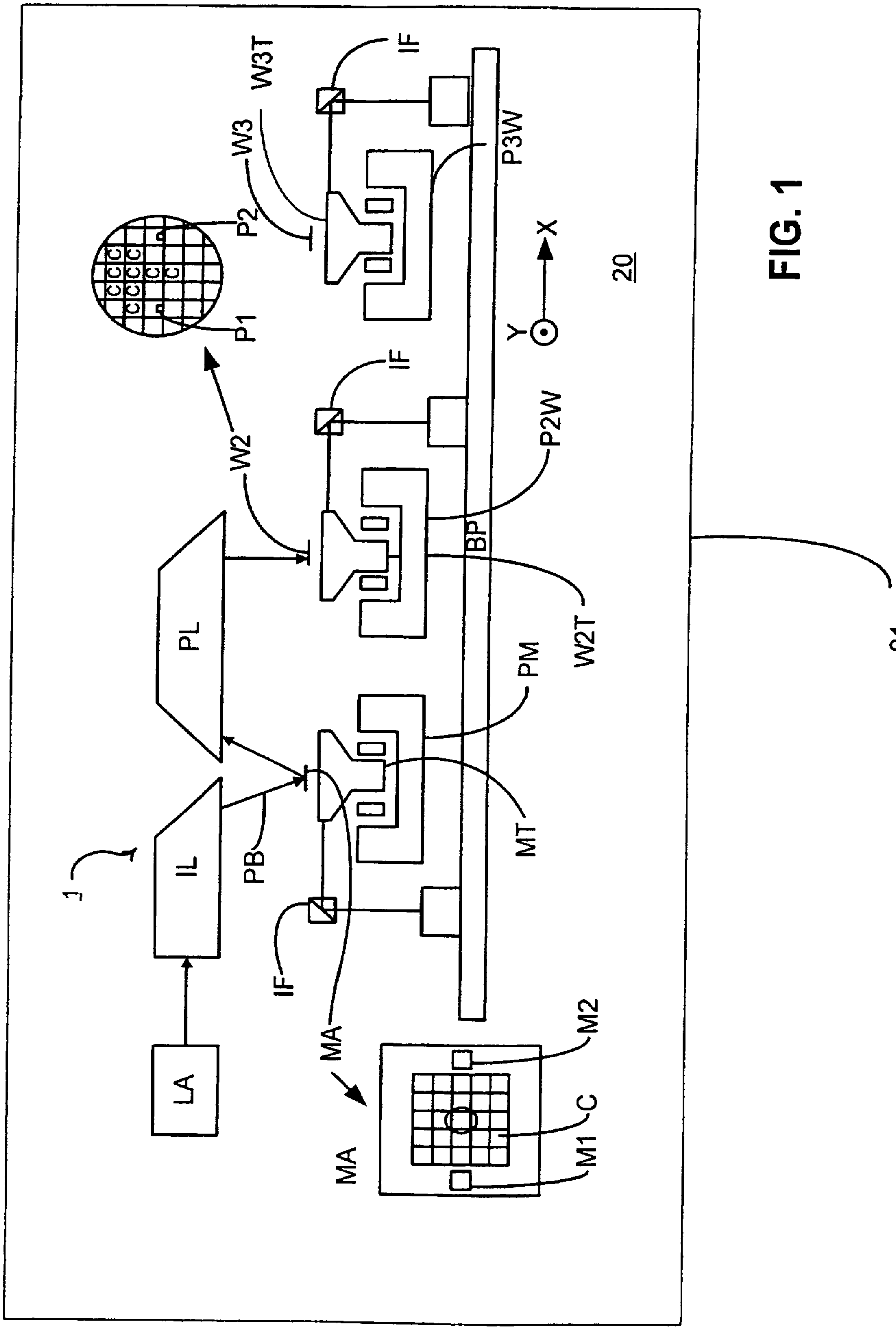
32. A device manufactured in accordance with the method of claim 31.

ABSTRACT

MOVEABLE CABLE SUPPORT FOR LITHOGRAPHY APPARATUS

A lithographic projection apparatus in which conduits which supply utilities to components in a vacuum chamber such as object tables and/or associated motors and/or sensors. The conduits are shielded from exposure to the vacuum by conduit conducts having at least the same number of degrees of freedom as their associated object table.

Figure 2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PB
PL
IF
MA
MT
PM
W2T
BP
P2W
W2
IF
P1
P2
C
W3
W3T
IF
P3W
X
Y
20
MA
M2
C
M1
21

FIG. 1

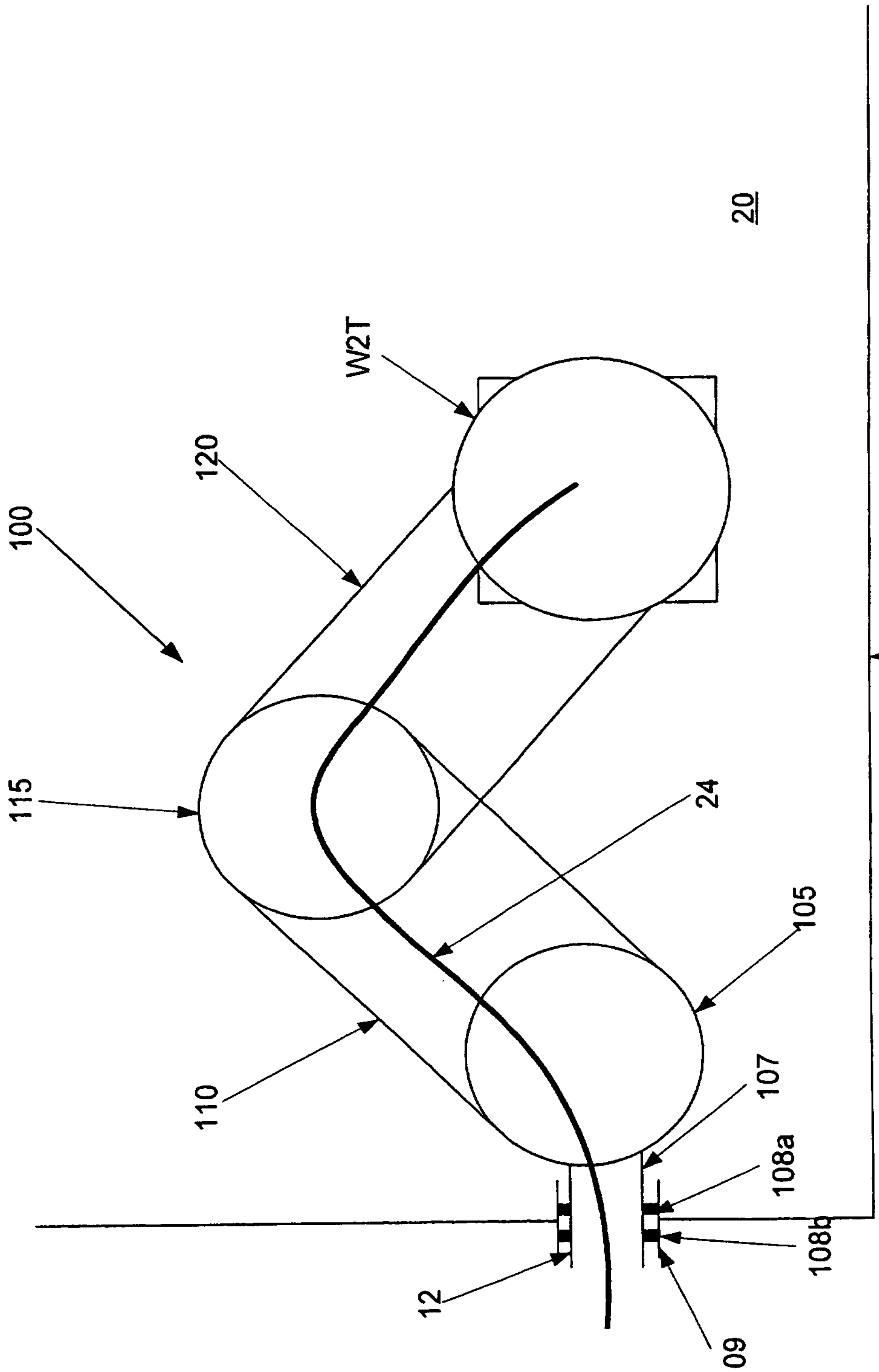

FIG. 2

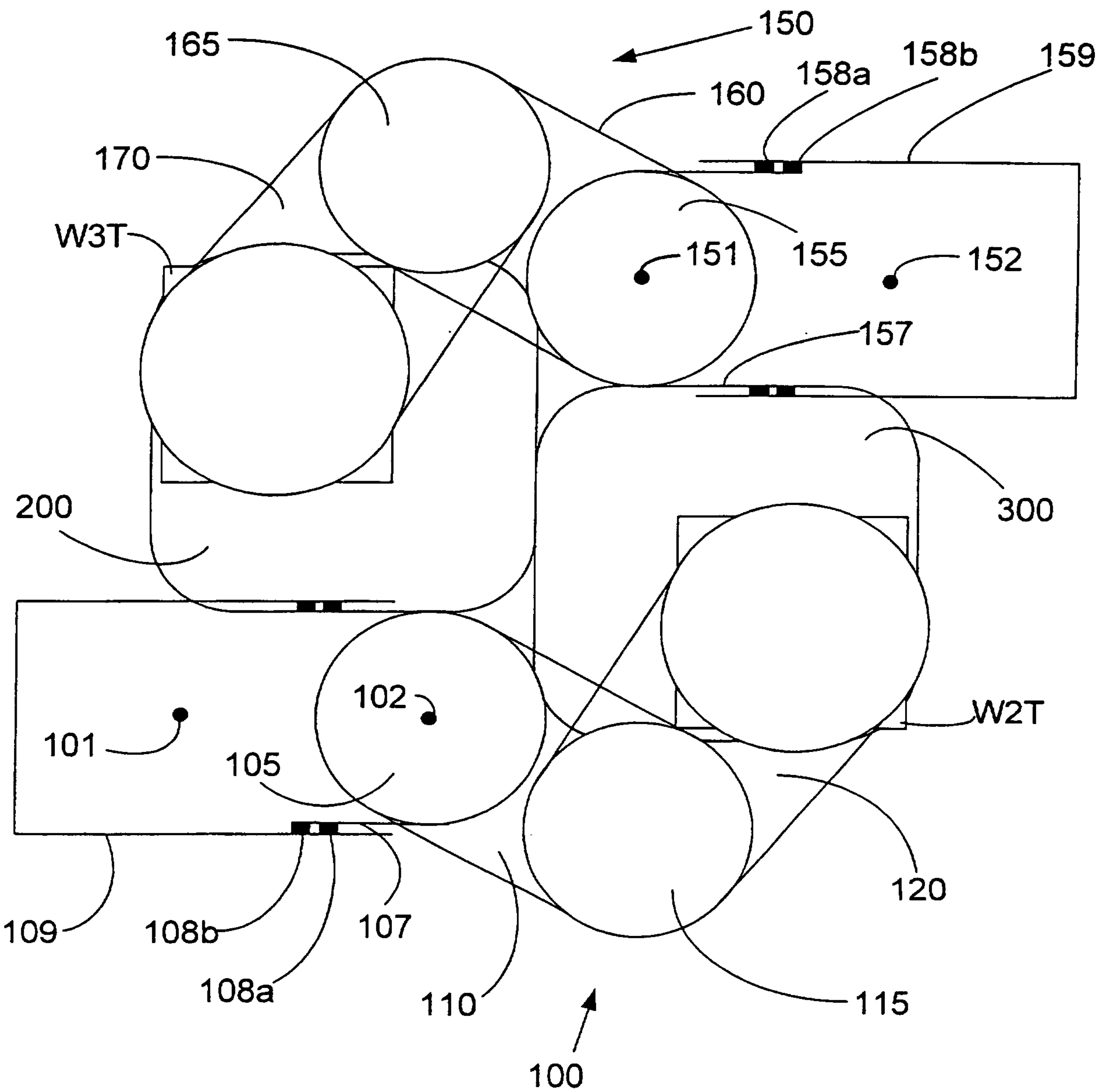
150
165
158b
159
158a
160
170
W3T
151
155
152
157
200
300
102
W2T
101
105
120
109
108b
107
108a
110
115
100

FIG. 3

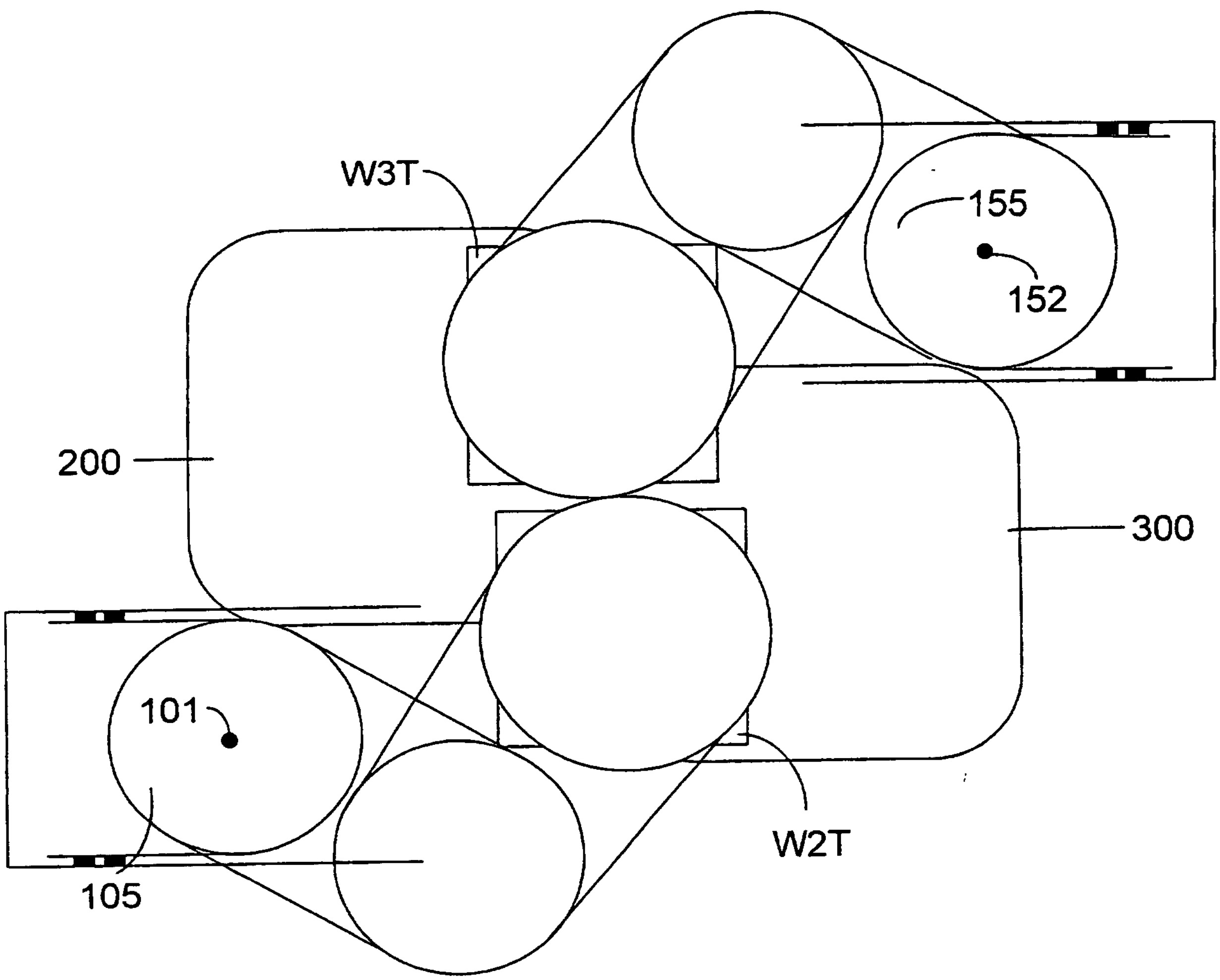

FIG. 4

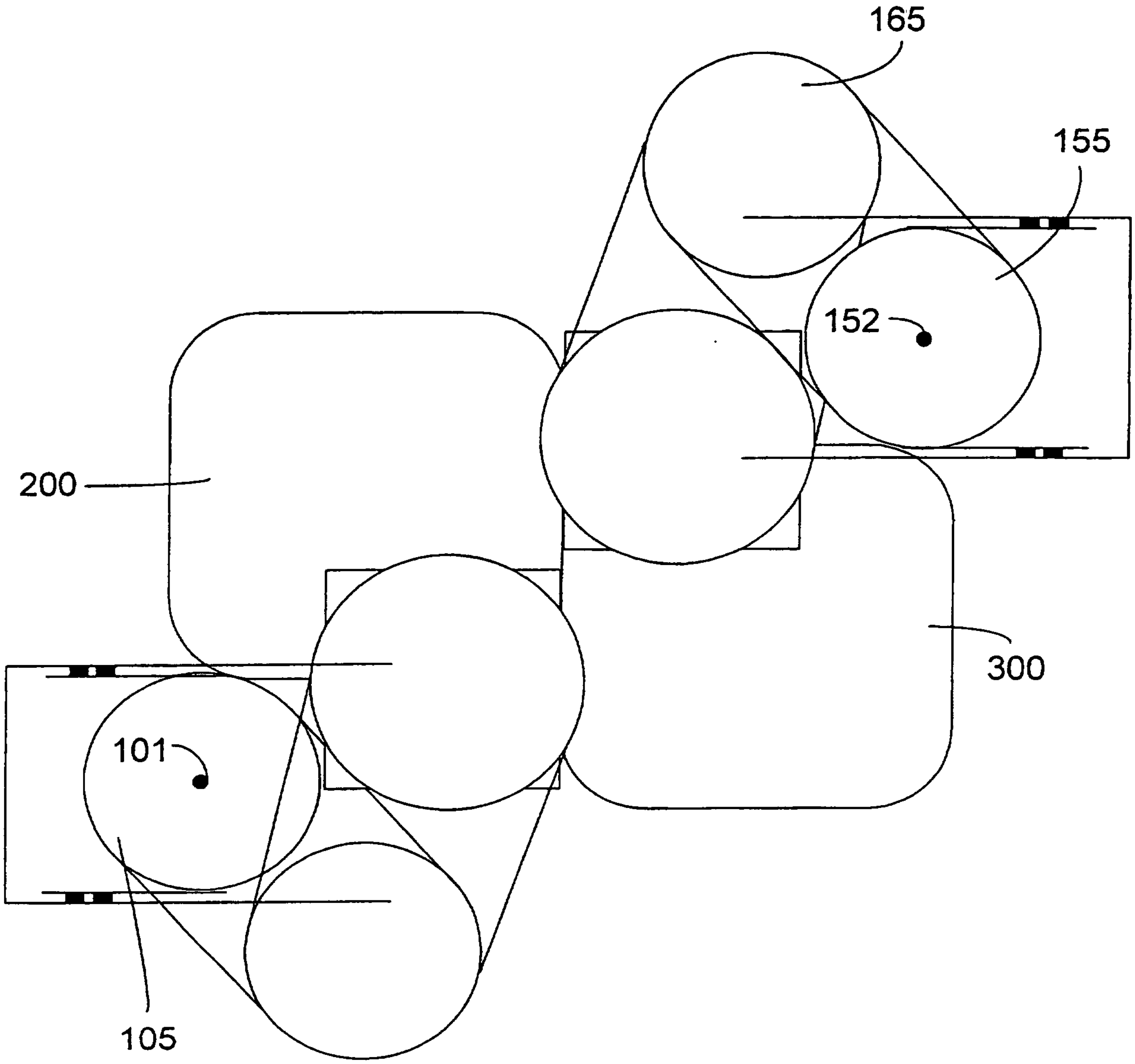

FIG. 5

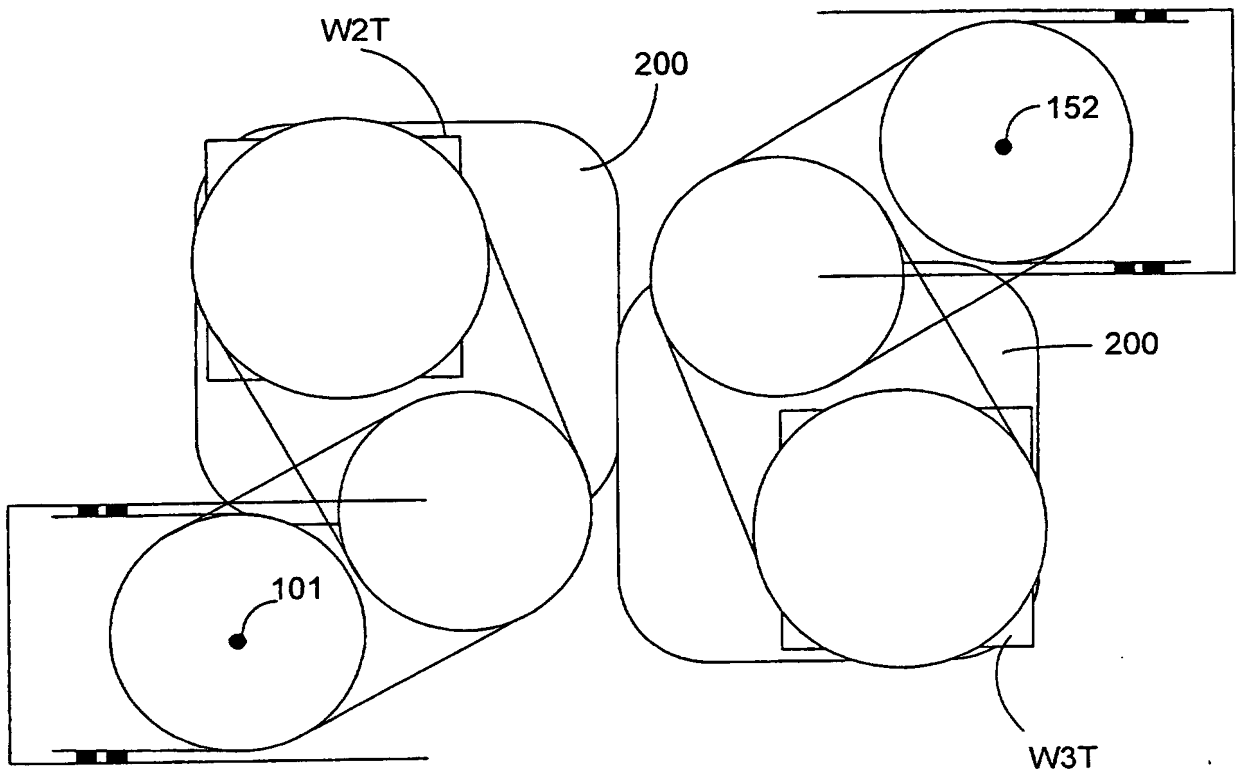

FIG. 6

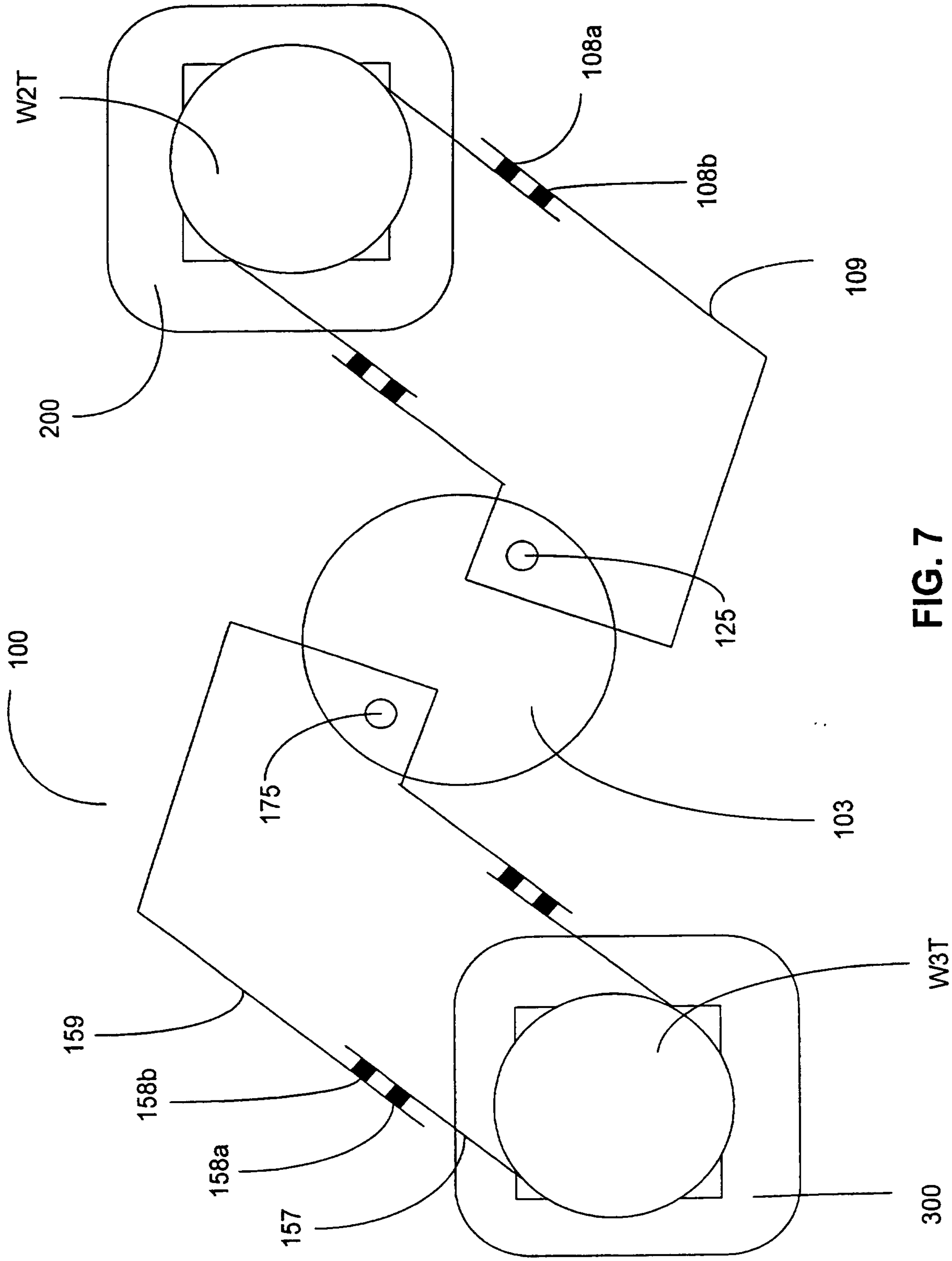

FIG. 7

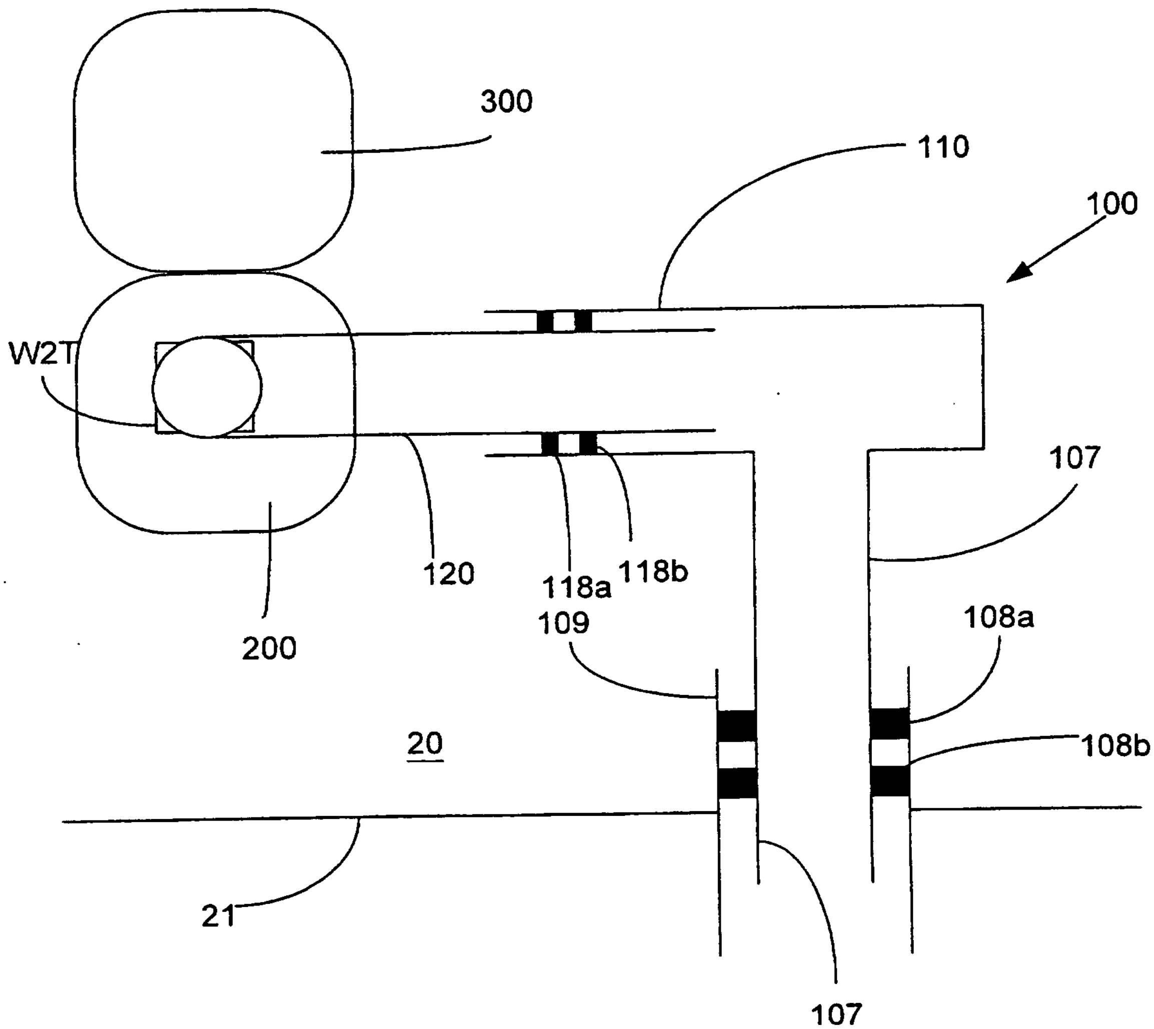

FIG. 8

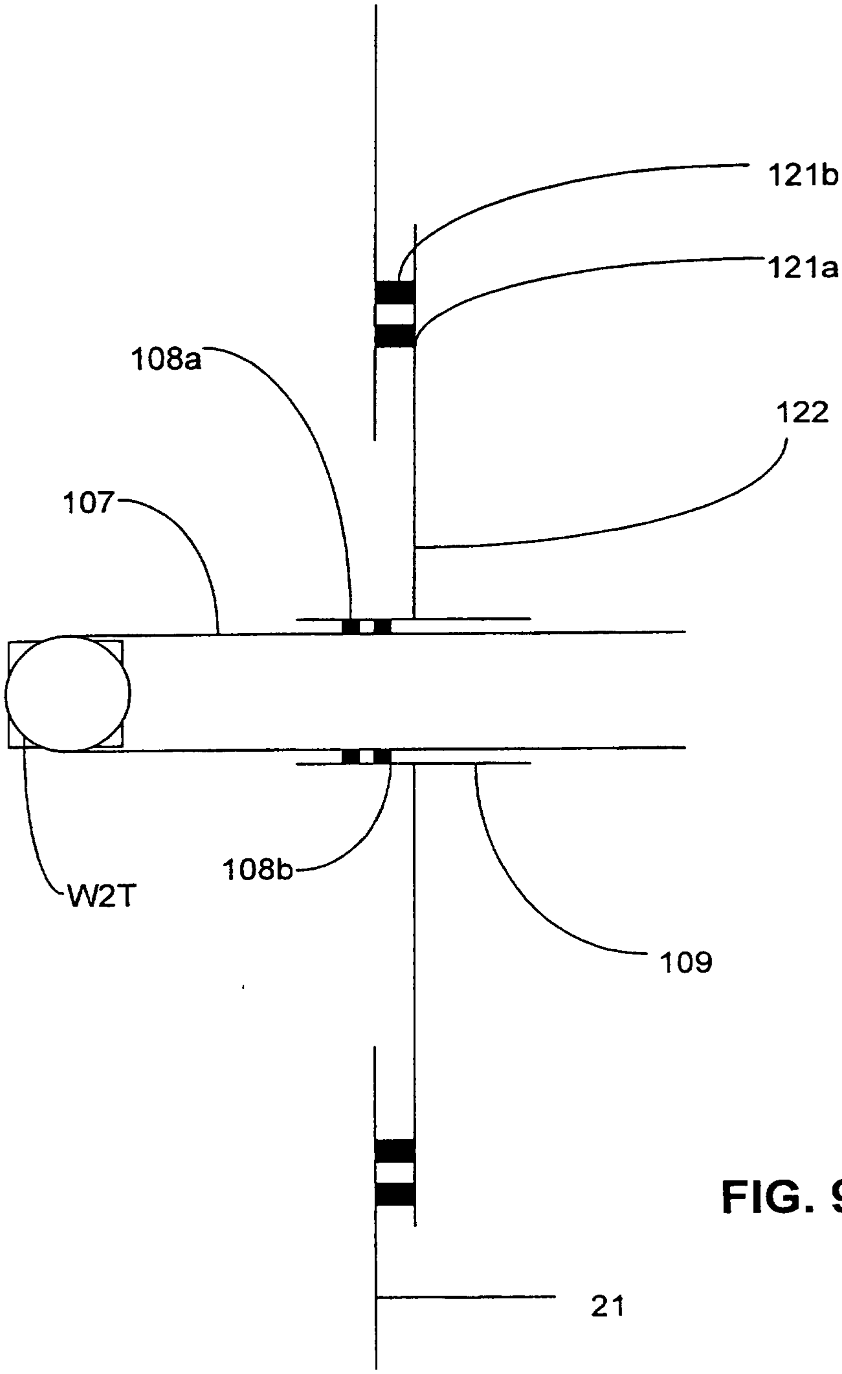

FIG. 9

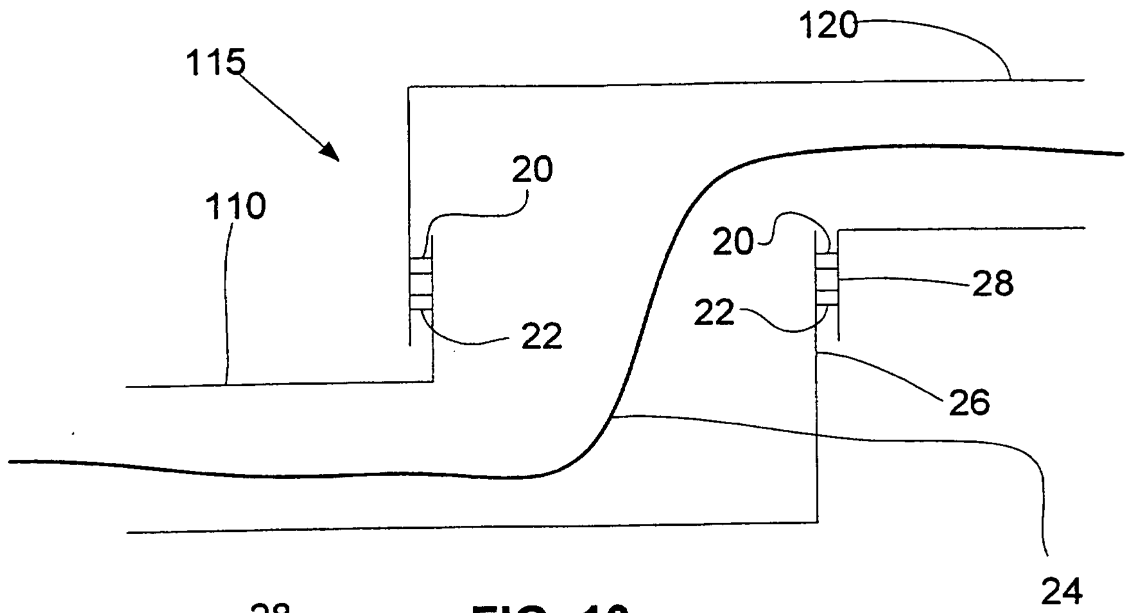

FIG. 10a

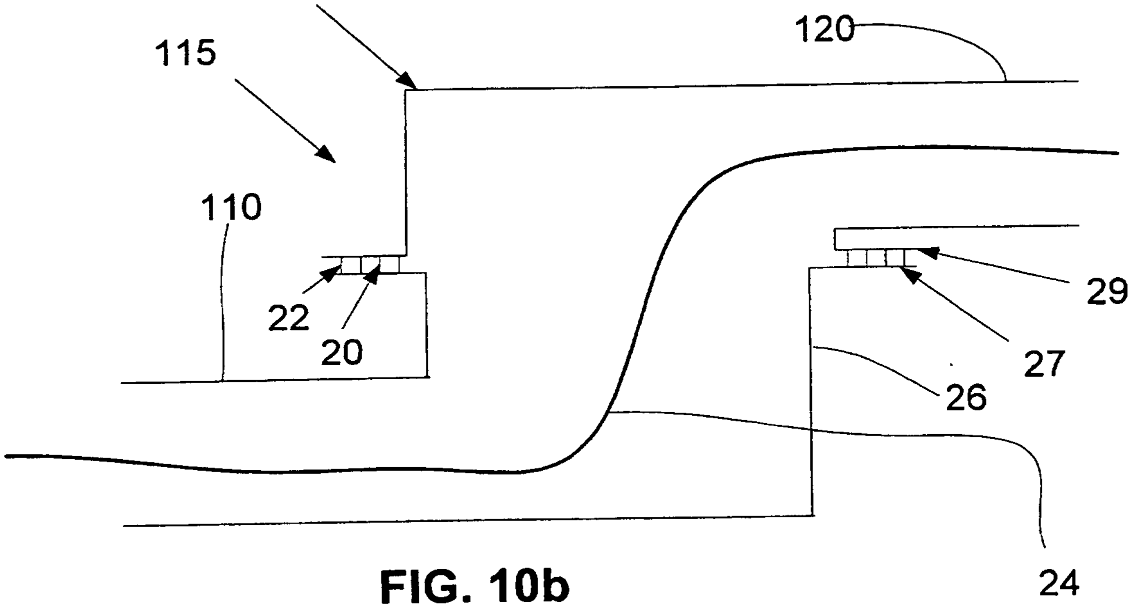

FIG. 10b

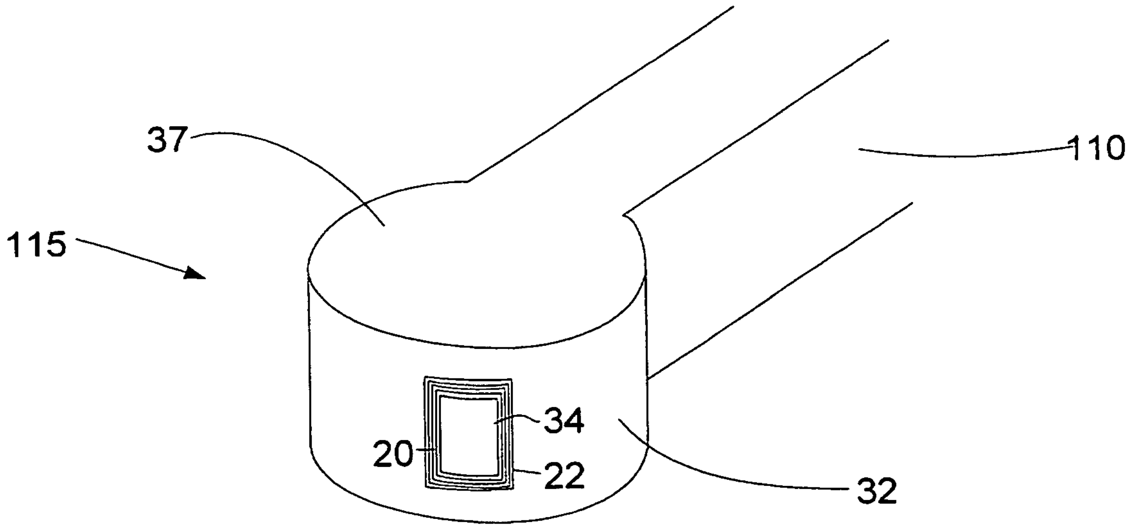

FIG. 11

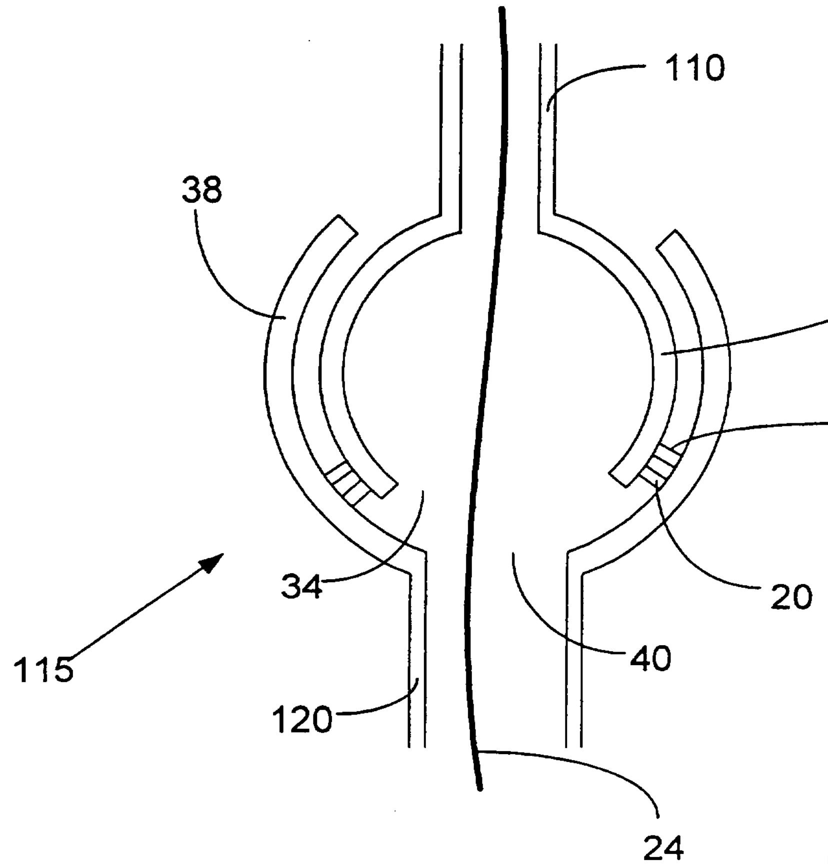

FIG. 12

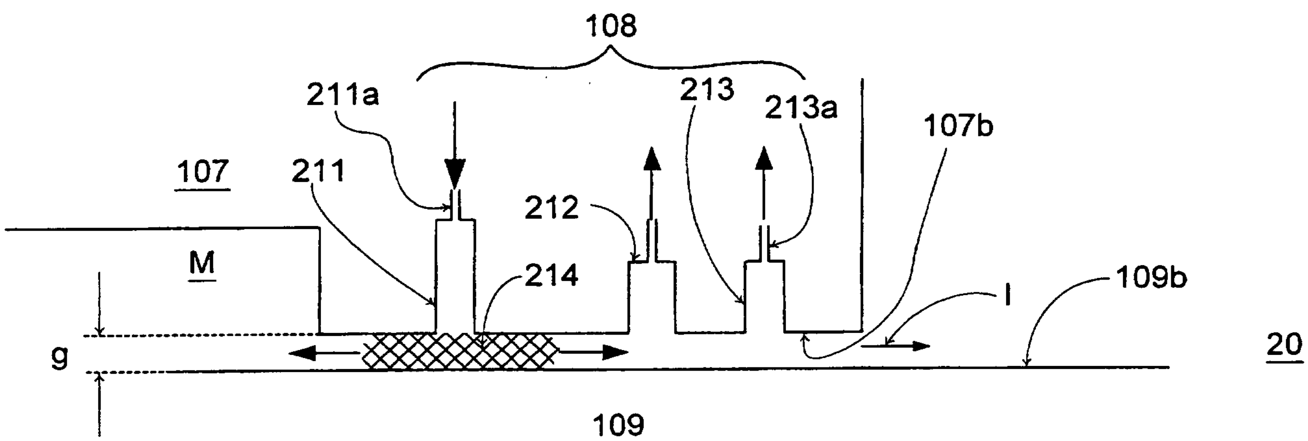

Fig. 13

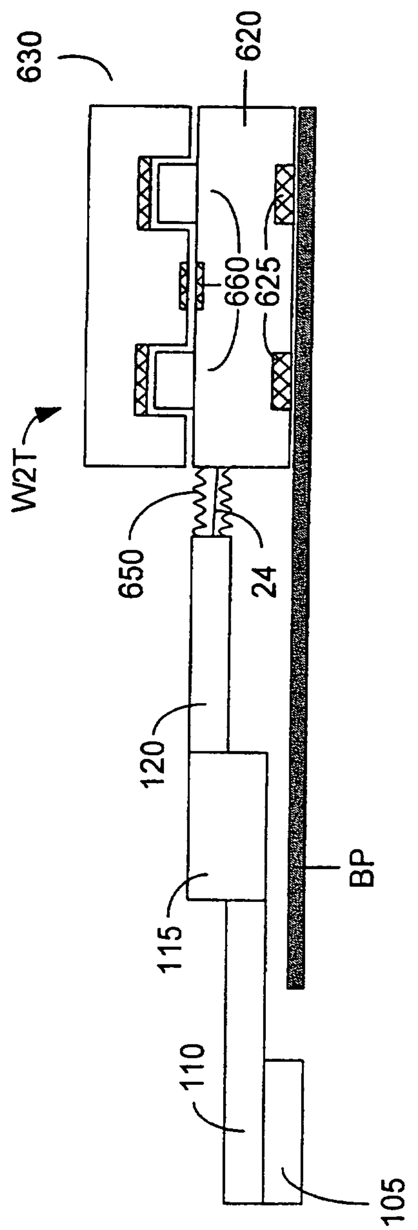

FIG. 14

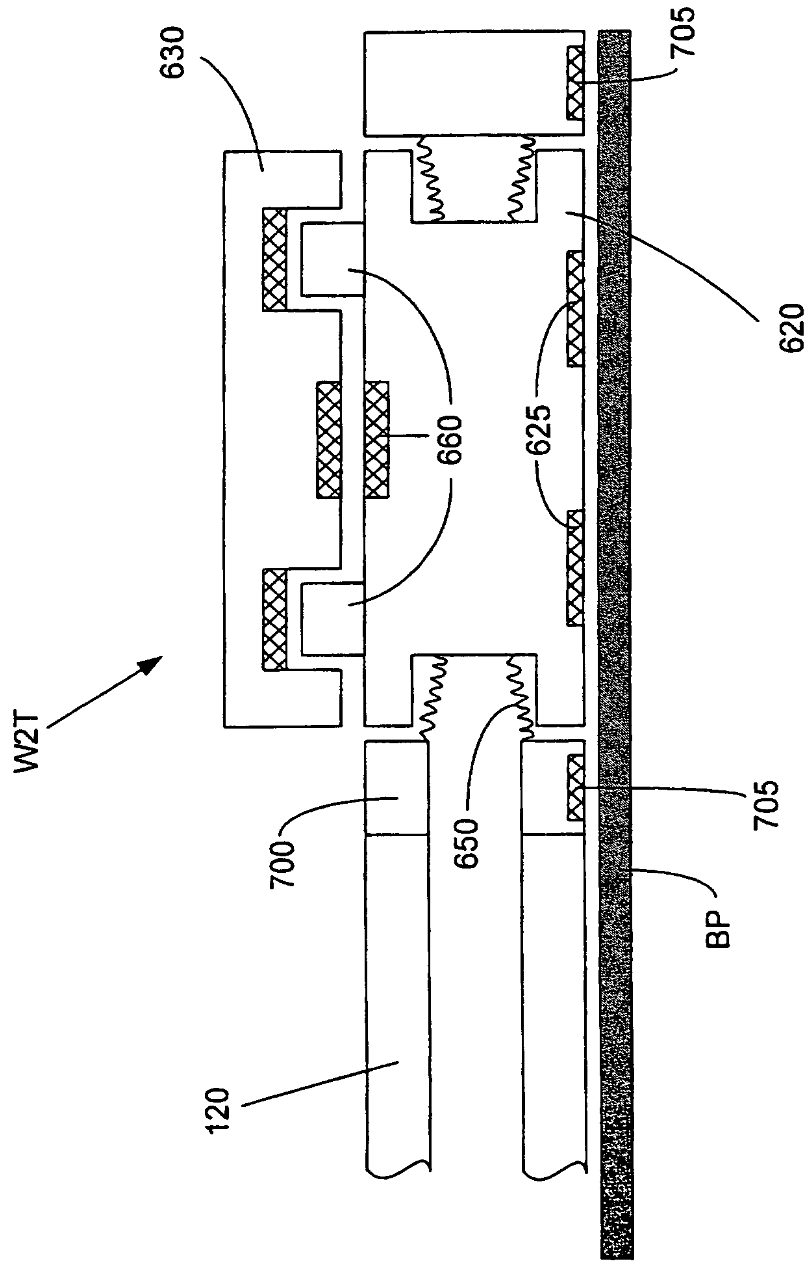

FIG. 15

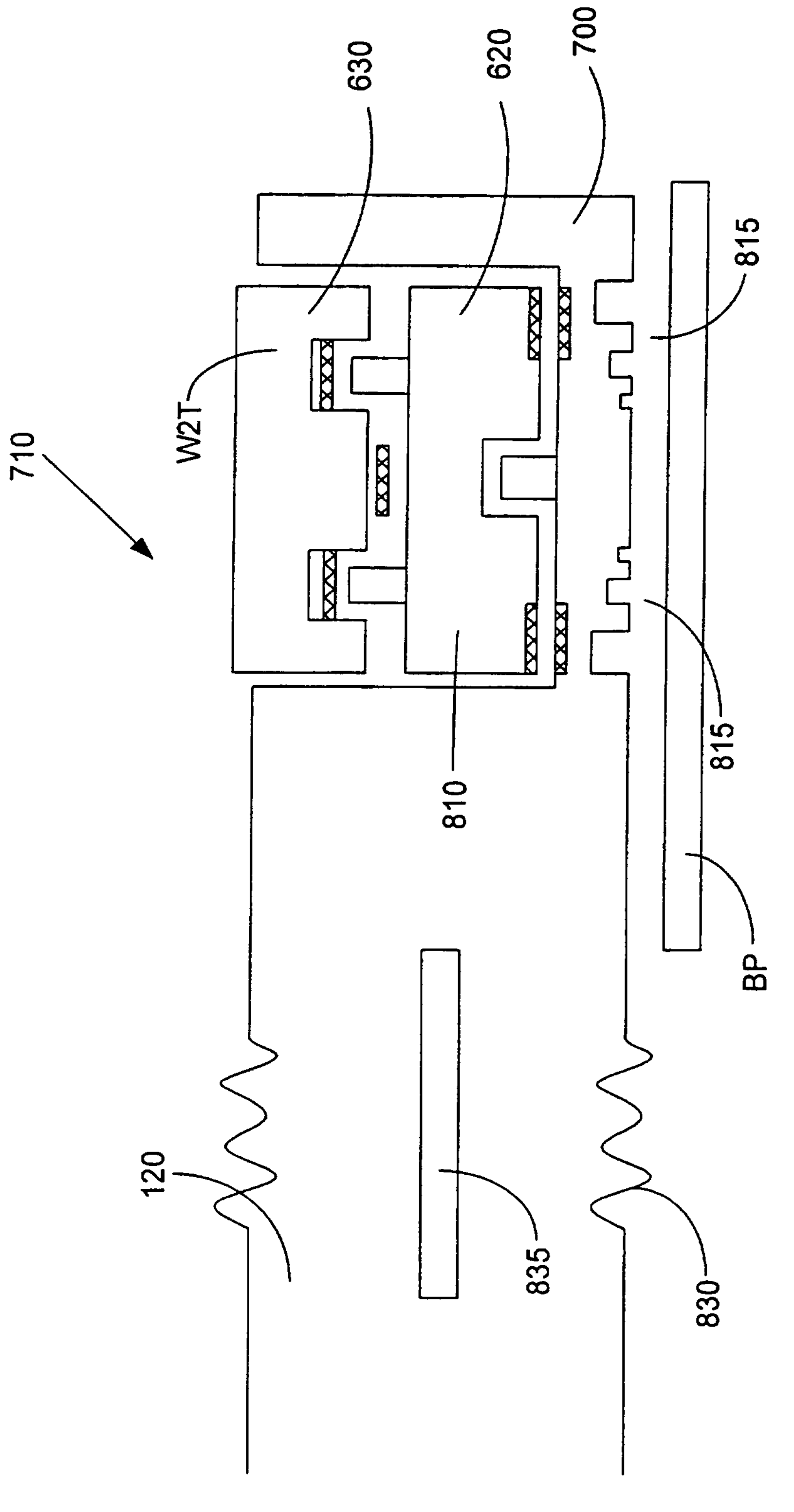

FIG. 16